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Obstacles to participation in carbon sequestration for nonindustrial private forest landowners in the southern United States: A diffusion of innovations perspective

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ABSTRACT

Forest carbon sequestration, resulting in increased carbon storage in forests, is an effective tool for climate change mitigation. Nonindustrial private forest (NIPF) landowner participation is crucial for increasing carbon stocks in the southern United States forests. Carbon sequestration is a relatively new practice, so NIPF landowners are expected to have varied adoption responses depending on their different internal (socioeconomic, financial, and forest structure factors) and external (environmental, governmental policy, and market factors) environments. This study identified major obstacles for NIPF participation in carbon sequestration and grouped landowners into adoption categories with respect to carbon sequestration using the diffusion of innovations model. Principal component analysis was used to identify five major obstacles to participation in carbon sequestration programs: revenue implications, forest characteristics, owner preferences, normative reasons, and understanding. NIPF landowners were grouped into three adoption categories: adopters (18%), majority (60%) and laggards (22%). The adopters, compared to the other categories, were richer, more educated, relatively younger, and owned larger landholdings. These results provide a valuable insight about the adoption behavior of NIPF landowners with respect to climate change mitigation programs in the southern United States. Program planners and outreach professionals should consider these NIPF landowner adoption categories and the role of peer landowners in promoting new programs and policies for developing effective mitigation strategies.

1. Introduction

Forest carbon sequestration is one of the important strategies for climate change mitigation. Trees sequester about 15% of total CO_2 emissions in the United States, which makes them one of the critical tools for reducing atmospheric CO_2 (EPA, 2011). Managing the southern United States forests for atmospheric carbon removal is an economical and efficient approach for climate change mitigation because trees increase carbon storage while reducing CO_2 emissions through substitution of industrial products (Malmsheimer et al., 2008). Depending on the management treatments they receive, forests could turn into a source as well as a sink of atmospheric carbon. Forest type and ownership goals determine the effectiveness of management treatments such as longer rotation, reduced disturbance, or increased productivity in increasing the carbon stock of a forest. In general, forest management strategies that increase timber volume or biomass production often support higher forest carbon sequestration levels (Hoover and Stout, 2007). Han et al. (2007) estimated that the southern United States has the potential to sequester about 23% of the regional total CO_2 emission.

In the southern United States region, where highly productive forests dominate the landscape and about 87% of the land is under private ownership, about 70% of that private land is owned by individuals or groups without wood-processing facilities, called nonindustrial private forest (NIPF) landowners (Oswalt et al., 2014). Their choice of forest management strategies will have an important role in climate change mitigation and carbon sequestration. Roughly 60% of total private carbon storage capacity potentially available for carbon sequestration in the southern United States is on NIPF forest land (Galik et al., 2013; Murray et al., 2005). Potential strategies for increasing forest carbon sequestration on NIPF lands include increasing acres devoted to carbon sequestration and implementing strategies to increase carbon storage at stand level. However, NIPF landowners in the South are a heterogeneous group with varied reasons for owning forest land (Khanal et al.,

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2017a; Majumdar et al., 2008) and very diverse management objectives (Arano and Munn, 2006; Butler, 2008; Joshi et al., 2015), which could create difficulties in increasing the carbon storage in the southern United States forests.

Earlier studies analyzing NIPF landowner participation in forest carbon sequestration programs can be broadly grouped into two classes based on the theoretical model they employed to explain the participation behavior of the landowners. One set of studies involved utility maximization as the rationale for NIPF landowners' interest toward carbon sequestration using econometric models to identify factors affecting their decision (Dickinson et al., 2012; Khanal et al., 2017b; Markowski-Lindsay et al., 2011; Soto et al., 2016). The results from these econometric models showed that sequestration program characteristics and financial reasons as well as socio- economics, understanding, and climate change attitudes had significant effects on NIPF landowner decision to participate in carbon sequestration programs. Among the southern United States landowners, Khanal et al. (2017b) and Soto et al. (2016) found similar results related to landowner participation in sequestration activities and that not every landowner is willing or qualified to participate in carbon sequestration programs. The second group of studies used the theory of planned behavior to explain NIPF participation behavior in carbon sequestration activities and found a strong association of landowner socio-economic factors with their attitudes and beliefs toward carbon sequestration (Khanal et al., 2016; Thompson and Hansen, 2012).

To explain the adoption of new practices such as carbon sequestration programs, some studies have applied sociological theories like the diffusion of innovations (DOI) model (Rogers, 2003), which describes transfer and adoption of new practices or technologies through a social system over time. Managing forest land for carbon sequestration is a relatively new practice, so it is highly plausible that NIPF landowners would adopt carbon sequestration practices over time. That means not every landowner would be expected to adopt carbon sequestration programs at the same time. Even if they were interested and qualified to become involved in carbon sequestration practices, NIPF landowners would likely have different adoption behaviors as described in the DOI theory. Doolittle and Straka (1987) first used this theory to evaluate forestry regeneration behavior of forest landowners in the southern United States. Recent studies have expanded its application to evaluation of adoption behavior and identify important communication channels to effectively communicate with forest landowners (Korhonen et al., 2013; Rametsteiner and Weiss, 2006). Rametsteiner and Weiss (2006) applied the theory to explain forest policy, while Korhonen et al. (2013) applied the theory to evaluate landowner participation in voluntary protection activities and to identify effective communication channels to influence their adoption behavior.

The goal of this study was to apply the DOI theory to forest landowners management situations related to carbon sequestration and to evaluate empirical data related to landowner's perceived obstacles for voluntary participation in carbon sequestration. The specific objectives were i) to identify major barriers for voluntary participation in carbon sequestration activities, ii) to identify adoption categories of forest landowners with respect to carbon sequestration in the southern United States., and iii) to evaluate the association of the adoption categories with landowners' socio-economic characteristics in the southern United States.

DOI theory highlights the importance of communication and peer-group learning for the adoption of a new practice in forestry. The innovators could serve as peer educators while the early adopters and early majority serve as opinion leaders or educators to the late majority and laggards concerning new practices such as forest carbon sequestration. The basis of the theory is the importance of communication channels for reaching out to landowners who put higher value on the opinion and practices of fellows or neighboring forest landowners (Doolittle and Straka, 1987; van Alphen et al., 2010; West et al., 1988).

2. Methods

Data for this study were collected using a mail survey of NIPF landowners with forest land in 11 states[1] in the southern United States. Counties without loblolly/shortleaf (*Pinus taeda/Pinus echinata*) or longleaf/slash (*Pinus palustris/Pinus elliottii*) pine forest groups based on Forest Inventory and Analysis (FIA) data were excluded from the survey. A contingent rating scenario included in our survey questionnaire required majority responses from NIPF landowners with pine forest types, but due to lack of such an exclusive database of the landowners, counties lacking the forest types were excluded. The names and addresses of NIPF landowners were purchased from List-Giant,[2] a private database vendor that compiles forest landowner lists based on county tax roll records. Thompson and Hansen (2012) also used the same vendor database for their NIPF forest carbon sequestration study. Additionally, consistent with previous landowner studies (Butler, 2008), our sample population did not include landowners with less than 10 acres of forest land in the selected counties. Less than 10 acres of forest land is not conducive to active forest management and these very small forested tracts are seldom included in surveys of this type (Thompson and Hansen, 2013).

A set of 17 survey questions were used to develop the rating variables used in the study. These questions were based on well-established barriers to DOI in terms of forest carbon sequestration (Markowski-Lindsay et al., 2011; Mitchell et al., 2012; Richards and Andersson, 2001; Szymanski, 2015). All questions had a basis of socioeconomic, personality, communication, and innovation characteristics and behaviors that allowed for development of five major obstacles to participation used in the analysis.

To prepare a survey questionnaire with clearly understandable questions and to elicit accurate information from landowners, a draft instrument was prepared and revised with input from U.S. forest landowner researchers. Then, the draft survey was pretested at county forestry association meetings (in Jefferson Davis and Lee counties) in Mississippi and subsequently refined. The final survey questionnaire included 32 questions using five pages. The survey instrument included three sections: forest land characteristics, environmental preferences, and socio- economic details. These represent basic demographic questions, but also identify barriers to adoption potential. Forest land characteristics addressed property size and type, ownership goals, and forest management strategies. Climate change, understanding of carbon sequestration, and interest-related questions were in the environmental preference section and the last section included income, education, and demographic related characteristics.

The survey was sent to 5000 randomly selected landowners in the fall of 2013 following the Dillman et al. (2014) tailored design method for conducting mail surveys. There were three mailings and the time between successive mailings was approximately three to four weeks. Each mailing included a signed cover letter, a survey questionnaire, and a postage-paid return envelope. A reminder postcard was sent to non-responding landowners between the first and second mailing only.

Out of 5000 surveys sent to the randomly selected landowners, only 4671 were valid addresses due to bad addresses, deceased individuals or no forest ownership. There were 735 completed responses received, resulting in a response rate of 15.7%. Most respondents were male (83%); the most frequent age category was older than 64 years (49%) and the most frequent income category was greater than $75,000 (54%). The low response rate may be likely due to political sensitivity of the climate change topic, limited understanding about climate change mitigation and forest carbon sequestration, and the complicated nature of the contingent rating scenarios included in the survey.

[1] Alabama, Arkansas, East Oklahoma, East Texas, Georgia, Florida, Louisiana, Mississippi, North Carolina, South Carolina, Virginia.

[2] List-Giant < http://www.listgiant.com > .

To test for potential non-response bias, we conducted a telephone survey of nonresponding landowners. Fifty randomly selected non-respondents were contacted by telephone and asked four key questions related to their forest land (i.e., size of largest forested parcel), management behavior (i.e., availability of written forest management plan), climate change belief (i.e., whether human activities are contributing to climate change), and education level attained. The respondents were given the response choices used in the survey instrument. In addition, non-response bias was tested by comparing late responding landowners (n = 100), as proxies for non-respondents, to early responding landowners.

Nonresponse bias test results showed that there was no statistical difference ($P > 0.10$) between responding and nonresponding landowners using a *t*-test in terms of forest land, management behavior, climate change attitude and education, suggesting nonresponse bias was not a concern. In addition, our sample was comparable to National Woodland Owner Survey results (Butler et al., 2016) in terms of average age, most frequently cited income category and the proportion of male and female owners in the South.

2.1. Diffusion of innovations model

The DOI model examines the spread of new practices or products into a social system over time and provides a definition of adoption categories depending on when an individual adopts a new idea (Rogers, 2003). It takes time for a new practice to be adopted in a social system because people have varied risk-taking behavior. This theory groups people into multiple categories depending on how long it takes for them to adopt a new technology or practice. The DOI model describes an underlying process that occurs as people adopt new practices in a social system.

This theory proposes five groups of individuals based on how, why, and at what rate the individuals adopt a new idea as compared to other members of a social system. The five categories of individuals based on the degree to which they adopt a new idea are innovators, early adopters, early majority, late majority, and laggards. The first group, innovators, are the venturesome, change agents, and risk-takers who are the first people to adopt any new invention or practice, while the laggards are mostly the followers, suspicious of new practices, and prefer the status-quo. Within a society, the early adopters, early majority, and late majority are likely to serve as opinion leaders, deliberate contact agents, and followers, respectively (Kaminski, 2011).

DOI studies tend to be quantitative using surveys, with a dependent variable based on adoption rate of some practice (total number of individuals or households that have adopted some practice). Independent variables center on adopter characteristics (socioeconomic position, use of media, networking activities, and adopter's use of non-local networking). Key factors influencing adoption are the perception of comparative or relative advantage of the practice, congeniality with related practices (compatibility), intricacies of adoption (complexity), ability to "test" the innovation before final adoption (trialability), and ability to measure results of the innovation (observability). Surveys allow for efficient collection of data related to demographics, appreciation of the innovation, networking experience regarding the innovation, and interactions with media and meetings involving the innovation (Meyers, 2004).

The DOI model has a fundamental assumption that the communications structure allows for the free flow of information or networking. Barriers can impede that flow, resulting in different diffusion rates. These barriers can be physical, social/cultural, or economic. An obvious physical barrier is distance, as adopters need access to each other. Social, religious, cultural or language differences can discourage adoption of innovations. Differing economic strata or technological complexity can slow adoption rates. It is important to consider how these barriers can have an important impact of the adoption potential of an innovation (Foxon and Pearson, 2008; Rogers, 2003).

2.2. Statistical analysis

Respondent ratings of the statements in Table 1 formed the basis for identifying NIPF barriers to participation in carbon sequestration. The list of statements was developed considering results of the earlier studies, which identified various factors influencing NIPF landowner participation in carbon sequestration in the United States. Earlier study results were evaluated and analyzed for relevancy so that statements would relate to the types of barriers discussed earlier (relative advantage, compatibility, complexity, trialability, and observability). In addition, the prior studies clearly identified statement types that related to forestry barriers. Respondents rated each statement using a Likert scale that ranged from one (strongly disagree) to five (strongly agree) with three indicating a neutral category. By using landowner rating responses in each statement, principal component analysis (PCA) was used to identify unobservable latent factors that contributed to the variation in ratings of the objective statements. The naming and

Table 1
Principal component analysis applied to seventeen barriers of participation statements related to carbon sequestration to identify five major obstacles for NIPF landowners in the southern United States.

Barriers for participation	Obstacles				
	Revenue implications	Forest land	Owner	Normative reasons	Understanding
It may decrease my revenue from the forest land	0.84	0.12	0.09	0.11	0.16
It could be in conflict with my other management goals	0.79	0.14	0.21	0.10	0.05
I worry this might decrease my property value	0.77	0.16	0.13	0.26	0.10
I think there is too much risk to implement forest carbon sequestration	0.52	0.27	0.39	0.19	−0.05
My forest characteristics are not suitable for this	0.18	0.81	0.18	0.09	0.03
I don't own enough forest land for carbon sequestration	0.12	0.71	0.20	0.10	0.28
I don't spend much time on my forest land to keep up with this	0.02	0.65	0.13	0.12	0.42
My other forest land contract obligations restrict me	0.37	0.61	0.03	0.08	−0.19
I don't want to change my current management practices	0.21	0.10	0.78	0.14	−0.03
I am too old to plan for carbon sequestration now	0.23	0.26	0.67	0.21	0.11
I am not willing to spend more money to implement this	0.12	0.14	0.59	0.08	0.32
None of my neighboring landowners are doing this	0.15	0.01	0.01	0.86	0.17
None of my neighboring landowners are interested in this	0.19	0.17	0.24	0.86	0.04
My family and friends are not interested	0.23	0.23	0.41	0.64	0.04
I don't know where to get advice about doing this	0.18	0.02	−0.04	0.05	0.82
I know very little about this to practice it on my land	0.03	0.24	0.17	0.12	0.71
I never thought about forest carbon sequestration	−0.04	0.02	0.50	0.06	0.56
Cronbach α	0.82	0.74	0.68	0.82	0.65

interpretation for each principal component dimension was based on higher component loading with original variables (i.e., correlation between original variables and the principal component). Components with greater than one eigenvalue were retained. This study followed the PCA method of Khanal et al. (2017a).

A non-hierarchical k-means analysis was applied to the landowner ratings of the obstacle statements. In this method, the final cluster centers are the mean of observations assigned to each cluster at complete convergence. For example, the k-means iterative clustering algorithm needed seven iterations to attain complete convergence and identify three cluster centers in our data. This means each observation was assigned to one of the three clusters to minimize its Euclidian distance from its cluster center. The minimization of the sum of squared distances from cluster centers ensured that the observations that were very close to each other got grouped into the same cluster, while the relatively distant observations fell into separate clusters (Charrad et al., 2014).

To name the three clusters, we calculated median values for the five participation obstacles determined in the PCA analysis. A variable with highest correlation coefficient under each participation obstacle was selected for the median estimation under each obstacle category. For example, under revenue implication obstacle, the variable *It may decrease my revenue from the forestland* had highest higher correlation coefficient. The variables *My forest characteristics are not suitable*, *I don't want to change my current management practices*, *None of my neighbors are doing this*, and *I don't know where to get advice about doing this* had higher correlation coefficients under forestland, owner, normative reasons, and understanding, respectively. Cluster naming depended on which participation obstacles had higher median values for each of the clusters. As described in the diffusion of innovation theory, the group with higher median value for the normative reasons and owner reasons was named “laggard group”, the group with least median values for each obstacles was named “adopters group”, while the group with majority of respondents and median values between previous two groups was named “majority”. The naming of these groups is arbitrary and reflects the group association attributes.

To validate the cluster numbers, Cubic Clustering Criteria (CCC) was computed for different number of clusters as suggested in SAS STAT 9.3 User's Guide, 2011. The cluster number with highest CCC indicated the best possible estimate of the number of clusters of the given dataset, i.e. local maxima. The number of clusters between one to five was tested, and the CCC local maxima (60.25) were associated with the three cluster solution, indicating three clusters were good estimates for the dataset. Then, the Pearson chi-square test of independence was used to test the association among adoption categories and socio-economic variables.

The non-parametric tests were used because the purpose of analysis was to test the association between adopter categories and selected socio-economic categories. The parametric modeling was not used because the purpose of analysis was not to test any hypothesis or make any definite statistical statement. Chi-square test served our purpose because it provides a measure of independence between rows and columns on n-by-n frequency tables formed by pairs of variables.

3. Results

3.1. Barriers for participation in carbon sequestration

The results from PCA of the 17 rating variables describing barriers for the landowners to manage their forest for carbon sequestration are presented in Table 1. The PCA described 79% of the variation when five major components were retained with a decision criterion of eigenvalue greater than 1. From the PCA, NIPF landowners' barriers to participation in carbon sequestration programs in the southern United States were broadly reduced into five major obstacle types: revenue implications, forest land, owner, normative reasons, and understanding.

The component loading coefficients of the barrier statements were between 0.86 to 0.52, indicating a strong correlation of the 17 statements with their associated new obstacle types. The statements *decrease my revenue, conflict with my other management goals, might decrease my property value, and risk to implement* can be thought of as describing the revenue implications related to implementing forest carbon sequestration. The loading coefficients of these statements were between 0.84 and 0.52. The statements *forest characteristics not suitable, not enough forest land, don't spend much time on forest, and other forest land contracts restrict* can be thought as describing their forest land characteristics related barriers for implementing carbon sequestration. These statements had loading coefficients between 0.81 and 0.61. The statements *don't want to change my current practices, too old to plan, no willingness to spend* could be described as owner characteristics related barriers for participation in carbon sequestration. The loading coefficients of these statements were between 0.78 and 0.59. The variables *none of the neighboring landowner doing, none of neighboring landowner participating, family and friends not interested* could be attributed as normative reasons for participation in carbon sequestration. These statements had loading coefficients between 0.86 and 0.64. The statements *where to get advice, know little about this, and never thought about it* could be attributed as the understanding related obstacles for participation in carbon sequestration. These statements had loading coefficients between 0.82 and 0.56.

3.2. Adoption categories of forest landowners

Results of the cluster analysis indicated that the survey respondents could be broadly grouped into three major categories (adopters, majority, and laggards) based on their rating of the 17 statements. These adopter categories relate to the barriers discussed earlier, with earlier adopters having characteristics that tend to reductions in the impact of barriers. In Table 2, the adopters were 18% of the total respondents, own 25% of forest acres in the southern United States, and had relatively lower ratings (less than 3.0) in each of the five barriers to participation in carbon sequestration. The majority represented 60% of the survey respondents, own 60% of the forest acres, and had higher ratings to all the five obstacle statements as compared to the adopters. Their rating of the normative causes was between early adopters and laggards. The other group, laggard was 22% of the survey respondents, own 15% of the forest land, and they rated all the five obstacles higher as compared with the other two groups. In particular, the normative

Table 2
Adoption categories of forest landowners, percentage in each category with respect to number of landowners and acre of forest land, and median rating of the obstacles for participation by each adoption category.

Adoption categories	% of N	% of acres	Median participation obstacles[a]				
			Revenue implications	Forest land	Owner	Normative reasons	Understanding
Adopters	18	25	2.3	1.9	2.4	2.8	2.8
Majority	60	60	3.0	2.8	3.1	3.1	3.4
Laggard	22	15	3.6	3.3	3.9	3.8	3.6

[a] Median participation obstacles indicate mid-point of the frequency distribution on the Likert scale rating between 1 to 5 with 1 (strongly disagree) to 5 (strongly agree) and 3 (neutral) response.

Table 3
Chi-square test of association among three adoption categories and their socio-economic characteristics in southern United States.

Variables	Adoption categories (%)			χ^2	Prob.
	Adopters	Majority	Laggard		
Management plan availability				12.54	0.0019
No	59.18	77.12	75		
Yes	40.82	22.88	25		
Land size (acres)				26.68	0.002
< 100	15.22	28.57	33.33		
100–500	61.96	62.34	63.16		
500–1000	15.22	5.52	1.75		
> 1000	7.61	3.57	1.75		
Income				43.65	0.0002
< 37,500	16.84	30.56	44.14		
37,500–62,500	6.32	17.28	16.22		
62,500–112,500	37.89	23.59	25.22		
112,500–175,000	18.94	10.96	6.3		
> 175,000	20	17.6	8.11		
Age				19.59	0.0033
< 40	3.00	2.69	2.38		
40–50	13.00	9.85	4.76		
50–60	32.00	21.79	13.49		
> 60	52.00	65.67	79.37		

and owner-related reasons received higher average ratings within this group.

3.3. Socio-economic association of forest landowner adoption categories

Results indicated that the three adoption categories were different in terms of the respondents' socio-economics, size of forest holding, and management behavior (Table 3). There were significant differences among the three adoption categories and their age distribution ($\chi^2 = 19.59$, $P < 0.0033$). In general, more than half of the landowners in all three adoption categories were over 60 years of age, but of the less than 50 years old landowners; more landowners were in adopters (16%) as compared to 11% and 6% in majority and laggards, respectively.

Similarly, there were significant differences among the three categories in terms of their annual household income distribution ($\chi^2 = 43.65$, $P < 0.002$). The most frequent income category for adopters (37%) was income between $62,500 and $112,500, but for the majority (30%) and laggards (44%) the most frequent income category was less than $37,500. Among adopters, 38% of the respondents earned more than $112,500 as compared to 27% and 14% in majority and laggards, respectively.

The adoption categories were significantly different in terms of their forest land size ($\chi^2 = 26.68$, $P < 0.002$) and the existence of a professionally-prepared forest management plan ($\chi^2 = 12.54$, $P < 0.0019$). The most common forest size among the three adoption categories was between 100 to 500 acres. More than 22% of the adopters had a forest land area greater than 500 acres as compared to late adopters and laggard groups with 8% and 2%, respectively. In terms of their availability of a forest management plan, more than 59% of the landowners in all three adoption categories did not have one. In adopter group, 40% of the landowners had a management plan but the majority and laggard groups with management plan were only 22% and 25%, respectively.

4. Discussion

This study identified major obstacles for NIPF landowner participation in carbon sequestration programs, and segmented landowners based on their adoption behavior towards new conservation practices in the southern United States. The five major obstacles for landowner participation were revenue implications, forest land characteristics, owner characteristics, normative reasons, and understanding of carbon sequestration. These findings are consistent with earlier studies related to factors affecting NIPF landowner participation in carbon sequestration programs, and augment the existing literature in an area that is critically important for effective policy design.

For NIPF landowners in Massachusetts, Dickinson et al. (2012) found that requirements for enrollment and longer time commitment negatively affected landowner participation, while education was positively associated with participation in carbon sequestration programs. Similarly, Markowski-Lindsay et al. (2011) found that management objectives, harvesting behavior, land size, and owner's income and age influenced landowners in Massachusetts to participate in carbon sequestration programs. Among southern United States landowners, Khanal et al. (2017b) found that their socio-economics, resource characteristics, and understanding affected landowner participation in carbon sequestration programs. The landowner-related factors such as attitudes influenced their participation in carbon sequestration programs (Khanal et al., 2016; Thompson and Hansen, 2012). Normative reasons were also important drivers for some forest landowners because they preferred to adopt 'tried and tested' techniques to avoid risk from new practices. We build on this literature, and add a more granular understanding of landowner barriers to carbon sequestration program participation.

The component loading coefficients, by use of the statements, effectively identify the barriers to adoption. Most important were uncertainty of expected revenue flow, forest suitability for effective adoption, unwillingness to adopt new practices that are not fully-established, lack of participation by peers, and lack of information and advice sources. Adopters were least affected by these barriers; the majority was moderately affected; and the laggards were most affected. Most useful are the socio-economic, forest holding size, and management behavior differences between the adoption categories.

Based on the rating of participation obstacles, there were three major landowner categories related to potential adoption of carbon sequestration practices in the southern United States. Our results are consistent with the DOI model, which predicts five categories of people related to the adoption of any new technology or practice: innovators, early adopters, early majority, late majority, and laggards. Our findings – driven by statistical inference – suggest a blurring of lines between the innovators and early adopters categories, and the early majority and late majority categories, in an NIPF carbon sequestration program context. Possible explanations include landowner homogeneity and characteristics inherent to carbon sequestration programs. NIPF landowners in the southern United States are relatively affluent, older, and less educated then the general population (Butler et al., 2016), so they could be considered a unique group, not a random sample of the general public in the region. These unique attributes of the NIPF landowners in the southern United States might have contributed to make the early and late majority categories less distinctive, and the very small predicted percentage of innovators (2.5%) in the traditional DOI model may have posed a challenge to finding statistical significance given our sample size.

Another possible reason is the lower understanding of forest carbon sequestration programs and their implications among NIPF landowners. In Khanal et al. (2017b), only 40% of the NIPF landowners in the southern United States indicated having a 'good understanding' of forest carbon sequestration, which is surprising. Awareness and understanding is an important precondition to adoption, and this very low level of understanding poses a significant barrier to the adoption decision.

Importantly, the laggard group of landowners rated normative reasons as a major factor in terms of barriers to adoption. This group is characterized as very inactive and risk- averse, and likely to follow practices adopted by their fellow landowners (Doolittle and Straka, 1987). Schubert and Mayer (2012) found that neighboring landowners are known to influence forest management decisions of their peers.

Similar to this study, group skepticism about new income opportunities was observed among landowners and such behavior was attributed to low social trust and lack of perceived control (Kreye et al., 2017).

In their study of NIPF landowners in Virginia, Vokoun et al. (2010) highlighted the need for cooperation in forest management decisions by different landowners. This peer group influence could be more effective at influencing forest management behaviors of the laggard landowners. Conversely, the adopter group of landowners had lower ratings across all the five obstacle categories as compared with the other two categories. This relates to better means to overcome the barriers identified earlier. Their major concerns were related to implications of participation in the sequestration practices.

As predicted by the DOI model, the obstacles or barriers were least potent for the adopter group, mid-level for the majority, and less potent for the laggard group categories. A homophily or peer association approach has been suggested for climate change education where the adopter group of landowners could serve as change agents or opinion leaders for forest carbon sequestration among NIPF landowners, while the majority group serves as contact agents for the laggard group of landowners (Monroe et al., 2015). Our results support this approach.

The landowner categories varied in terms of their socio-economic and behavioral characteristics as well. Members of the adopter category were relatively younger, earned higher incomes, and owned larger forest holdings than members of the majority and laggard categories. This supports prior research that found landowners in the adoption category to be relatively young and adventurous with more education, higher income, larger forest holdings, professionally-prepared forest management plans, and more receptive to alternative forest management practices (Joshi et al., 2015). Other research associates higher income and size of forest holding with landowner objectives that favor forest protection and stewardship (especially if other incentives like carbon sequestration are options), suggesting adopters would be favorable to practices like carbon sequestration and majority landowners were likely to keep up with the competition and follow suit (Kline et al., 2000).

The early adopter categories are more likely be active, information seeking, and relatively young landowners, so they would be an easily accessible group to deliver contents related to carbon sequestration. The laggard group would be more passive in terms of management and information seeking behavior, so it could be difficult to connect with these landowners. The early adopters or majority might be willing to adopt new practices with little information, but the laggard group may need intensive outreach, and may require site visits or demonstration tours for convincing that the new information will actually work for them. Therefore, it may be beneficial to utilize multiple communication strategies that are tailored to these groups to influence adoption behavior in a forest carbon sequestration program context. Finally, these adoption categories were based solely on results of the PCA and cluster analysis of the 17 rating variables on barrier to participation. The results of this study describe potential or theoretical adoption characteristics based on a predictive model that should approximate actual forest owner behavior.

5. Conclusion

Using cluster analysis and principle component analysis, we identified three discrete landowner groups related to the adoption or potential adoption of forest carbon sequestration programs in the southern United States. Our results were consistent with the DOI model, though we found only three rather than five categories predicted by the model. Results can be used to tailor program features, and associated outreach and education activities, to better reach and motivate forest landowners to participate in forest carbon sequestration programs that may benefit them.

The findings of this study can be used to identify forest owners most likely to participate in the successful implementation of a forest carbon sequestration program in the southern United States. We found that the adopter and majority categories would be the most valuable groups to concentrate on initially to gain acres of carbon sequestration. With proper communication strategies to influence the forest management behavior of these two groups of landowners, particularly with the help of change agents and opinion leaders within these groups, they would likely be more receptive to carbon sequestration information if supplemented by adequate incentive provision.

Measells et al. (2005) found that NIPF landowners in Arkansas, Louisiana, Mississippi, and Tennessee had varied preferences to receive forestry-related educational programs depending on their socio-demographic characteristics, size of forest holding, and reasons for owning forest land. Therefore, adopter and majority landowner categories would require different communication strategies to influence behavior related to forest management practices. In the context of changing forest landscape like shrinking forest acres, communication to pursue NIPF landowners in ecosystem services or carbon sequestration is essential, but complicated (Belin et al., 2005; Hatcher Jr. et al., 2013). Thus, diverse channels of communication would be required to approach the landowners associated with the different adoption categories.

For example, the use of site visits, ‘walks in the woods’, or demonstration tours could prove to be particularly useful for the laggards group, and identifying change agents and opinion leaders may be critical to helping landowners transition from one adoption group to the next. Likewise, we see the strong role for economic incentives amongst the adopters, and the role for group norms in motivating adoption. Adequate incentive or policy support would be needed to enroll a significant percentage of landowners in this region. Our results point to a need for diverse and tailored approach to communicate with NIPF landowners with diverse adoption characteristics and obstacles to participate in carbon sequestration. Future work can build on these findings to help predict landowner adoption and the number of forest acres available for enrollment in forest carbon sequestration in the southern United Sates.

These results have application to landowner participation in a wide range of forestry programs, well beyond carbon sequestration. While the survey was limited to a region of the United States, the results would apply to landowners in any forested region.

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